The switching status of the proposed PWM is listed in Table 1 and 2 for rectifier mode and inverter mode operation, respectively.

Table1: Rectifier mode switching combination

	Status	S_1	S_4	S_3	S_2	
Vs>0	A	OFF	OFF	ON	OFF	$V_L>0$
	B	OFF	ON	OFF	OFF	
	E	OFF	OFF	OFF	OFF	$V_L<0$
Vs<0	C	ON	OFF	OFF	OFF	$V_L<0$
	D	OFF	OFF	OFF	ON	
	E	OFF	OFF	OFF	OFF	$V_L>0$

Table 2: inverter mode switching combination

	status	S_1	S_4	S_3	S_2	
Vs>0	F	ON	OFF	OFF	OFF	$V_L>0$
	G	OFF	OFF	OFF	ON	
	H	ON	OFF	OFF	OFF	$V_L<0$
Vs<0	I	ON	ON	OFF	OFF	$V_L<0$
	J	OFF	OFF	ON	OFF	
	K	OFF	ON	ON	OFF	$V_L>0$

For explanation of how the proposed PWM works, consider the single phase bidirectional AC/DC converter system as shown in fig 1 and assuming that AC grid system has the internal impedance which is highly inductive which is represented by L. Considering the equivalent series resistance (ESR) of inductor is negligible.

3. Rectifier Mode

The switching combination of the proposed PWM operated in the rectifier mode is listed in Table 1. In positive half cycle of ac grid voltage source i.e. when $V_s>0$, the switching of switches is as status A and status B as listed in Table 1. In status A switch S_3 is turned on and inductor current path is $V_s - L - D_{S1} - S_3 - V_s$ and in status B switch S_4 is turned on and inductor current path is $V_s - L - S_4 - D_{S2} - V_s$. Using Kirchhoff's voltage law the voltage relationship is:

$$Vs - L\frac{d}{dt}i = 0 \quad (2.1)$$

While $V_s>0$, in both status (status A and status B) the inductor current is increasing and the voltage across the inductor is V_s. Therefore in both this conditions (status A and status B) the inductor current is in charging state. In both this cases load voltage is greater than zero ($V_L>0$).

In positive half cycle when all switches are tuned off that is when the converter is in status E. In this status as all switches are turned off the inductor current takes the path of $V_s - L - D_{S1} - C - D_{S3} - V_s$. Using Kirchhoff's voltage law the voltage relationship is:

$$Vs - L\frac{d}{dt}i - Vdc = 0 \quad (2.2)$$

The inductor voltage is $V_s - V_{dc}$ and inductor current decreases. Therefore, in this case the inductor is in discharging state. In this case load voltage is less than zero ($V_L<0$).

Considering the negative half cycle of the ac grid voltage source i.e. when Vs<0, the switching of switches is as status C and status D in Table 1. In status C switch S_1 is turned on and inductor current path is $V_s - L - S_1 - D_{S3} - V_s$ and in status D switch S_2 is turned on and inductor current path is $V_s - L - D_{S4} - S_2 - V_S$. Using Kirchhoff's voltage law the voltage relationship is:

$$Vs - L\frac{d}{dt}i = 0 \quad (2.3)$$

While $V_s<0$, in both status (status C and status D) the inductor current is decreasing and the voltage across the inductor is V_s. Therefore in both this conditions (status C and status D) the inductor current is discharging state. In both this cases load voltage is less than zero ($V_L<0$).

In negative half cycle when all switches are turned off that is when the converter is in status E. In this status as all switches are turned off the inductor current takes the path of $V_s - L - D_{S4} - C - D_{S3} - V_s$. Using Kirchhoff's voltage the voltage relationship is:

$$Vs - L\frac{d}{dt}i + Vdc = 0 \quad (2.4)$$

The inductor voltage is $V_s + V_{dc}$, and the inductor current increase. Therefore, in the case the inductor is in charging state. In this case load voltage is greater than zero ($V_L>0$).

As a summary, in positive half cycle of ac grid voltage source $V_s>0$, both status A and status B the inductor current increases and status E the inductor current decreases to achieve ac current shaping and dc voltage regulation. While in negative half cycle of ac grid voltage $V_s<0$, both status C and status D the inductor current decreases and status E the inductor current increases to accomplish ac current shaping and dc voltage regulation. Regardless whether the ac grid voltage source is operating in the positive half cycle $V_s>0$ or negative half cycle $V_s>0$, the converter inductor current can be increased or decreased properly in the proposed PWM operation in rectifier mode.

4. Inverter Mode

The switching combination of the proposed PWM operated in the inverter mode is listed in Table 2. When the converter is operated in the inverter mode the actual inductor current is in the reverse direction compared to the ac grid voltage. In positive half cycle of ac grid voltage source i.e. when $V_s>0$, the switching of switches is as status F and status G as listed in Table 2. The input current is in the reverse direction $i_L<0$. In status F switch S_1 is turned on and inductor current path is $V_s - L - S_1 - D_{S3} - V_s$ and in status G switch S_2 is turned on and inductor current path is $V_s - L - D_{S4} - S_{S2} - V_s$. Using Kirchhoff's voltage law, the voltage relationship is:

$$Vs - L\frac{d}{dt}i = 0 \quad (2.5)$$

In both this conditions (status F and status G) the inductor current is in charging state. In both this cases load voltage is greater than zero ($V_L>0$).